

# **Sediment Mixing in Coastal Regions: The Impact of Animal Digestion on Radionuclide Tracers**

Lawrence M. Mayer  
Darling Marine Center, University of Maine  
Walpole, ME 04573  
phone (207) 563-3146 ext 237 fax (207) 563-3119 email [lmayer@maine.edu](mailto:lmayer@maine.edu)

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<http://www.ume.maine.edu/~marine/mayer.htm>

## **LONG-TERM GOALS**

We focus on measurement of, and controls on, bioturbation in marine sediments. We seek to further our understanding of the solubilization of metallic elements during passage of marine sediments through the digestive systems of deposit feeders. Of particular interest are the implications of this solubilization for the dissolution of metallic contaminants in sediments and the metallic radionuclides used in measuring sediment bioturbation.

## **OBJECTIVES**

We will test for the chemical mechanisms by which various metals are solubilized by the ligands present in digestive fluids. We hope to isolate specific ligand groups involved in binding the metals. We will also test if metallic radionuclides used in bioturbation, such as  $^{234}\text{Th}$  and  $^{210}\text{Pb}$ , are significantly solubilized by digestive fluids. If so, we will assess what matrices holding these radionuclides are particularly vulnerable to the dissolution process. We will determine the frequency of gut passage in the field and explore the use of biomarkers, such as chlorophyll and carotenoid pigments, as indicators of gut-passage frequency. Implications for published and developing models of bioturbation will be assessed based on these results.

## **APPROACH**

Initially, our general approaches were to (1) to conduct incubation experiments with gut fluids of deposit feeders to assess the amount of metallic radionuclides solubilized from the sediments, (2) to determine both intrinsic (organismal) and extrinsic (sedimentary) factors contributing to the solubilization, and (3) to corroborate the incubation experiments with *in vivo* solubilization and bioaccumulation measurements. A fourth approach, developed during this project, is to determine the products of phytoplankton-pigment degradation during deposit-feeder gut passage and seek these compounds in field samples as markers for gut passage.

## **WORK COMPLETED**

We have completed a series of experiments to examine the dissolution of radionuclides in deposit-feeder digestive fluids, and have a manuscript near completion. These results demonstrate the importance of gut-passage frequency in determining which solid phases bind radionuclides in the field. We have followed up on these experiments by developing techniques to determine gut-passage

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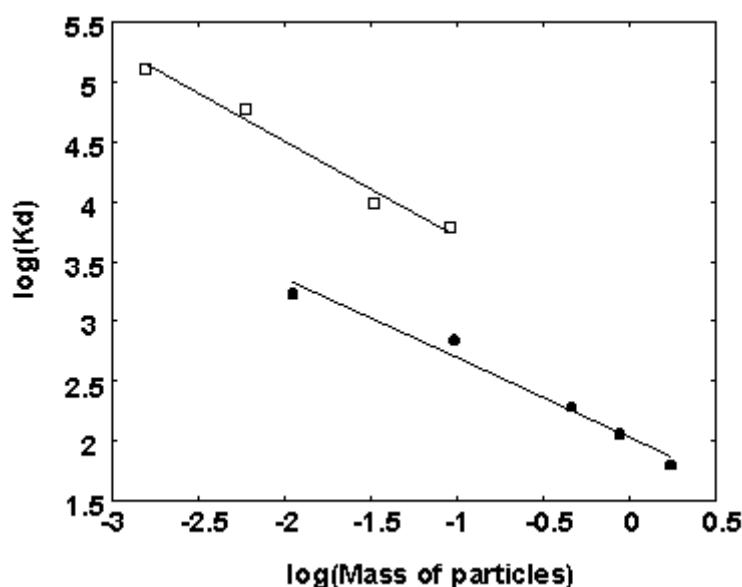
frequency in the field. We have performed a series of experiments examining degradation of phytoplankton pigments in deposit-feeder digestive fluids. Certain chlorophylls and carotenoids were found to be rapidly degraded in deposit feeder guts, and may be promising geochemical markers for gut passage.

In order to determine the frequency of gut passage in the field, we performed a field survey of the Damariscotta Estuary, coastal Maine, identified two stations for intensive field study that vary strongly in macrofaunal abundance and community structure, and collected samples from these sites with a box corer. These samples are now being analyzed for phytoplankton pigments, radionuclides, benthic infauna, X-ray radiography, and a variety of indicators of food quality and sediment bulk properties.

## RESULTS

We extended our previous experiments to comprise a suite of radioisotopes including  $^{234}\text{Th}$ ,  $^{210}\text{Pb}$ ,  $^7\text{Be}$ , and  $^{137}\text{Cs}$ . Kinetics experiments showed that most dissolution reactions occur within minutes, although  $^{234}\text{Th}$  can require hours to reach steady state. We found appreciable gut fluid dissolution of  $^{234}\text{Th}$ ,  $^{210}\text{Pb}$ , and  $^7\text{Be}$  from algal detritus labeled with these isotopes.  $^{137}\text{Cs}$  was also desorbed from clays at low concentrations in gut fluid. Further experiments examined the partitioning of radionuclides among algal, mineral, and digestive-fluid phases. Upon addition of unlabeled sediment particles in concentrations ranging up to those found in *A. marina* midguts, little net dissolution occurred, indicating that dissolved radionuclides were resorbed by solid phase ligands on mineral surfaces. Algal material sorbs these radionuclides more effectively than sediment. These results provide a mechanism for the observation that radionuclides with short half-lives are mixed more rapidly than those with longer half-lives. Gut passage redistributes longer-lived tracers onto mineral phases of particles that are selected less frequently by deposit feeders than organic particles enriched in both nutrition and water column-derived radioisotopes.

Our laboratory experiments with phytoplankton pigments have explored the kinetics and extent to which chlorophylls and carotenoids are degraded during gut passage, and show that significant but not complete degradation can be expected within normal gut residence times. Our preliminary analyses of pigments and radioisotopes downcore in coastal sites show the usual exponential decay with depth along with subsurface peaks that correspond with elevated concentrations of labile organic matter. These results will be joined with innovative modelling approaches to determine pigment decay kinetics and gut passage frequency of various particle types assuming nonlocal transport events.



*Apparent distribution coefficients for  $^{234}\text{Th}$  decrease with increasing particle concentration, with the algal material showing  $K_d$ 's about an order of magnitude higher than sediment.*

## IMPACT/APPLICATIONS

These results indicate that deposit feeders can dissolve algal-bound, particle-reactive radionuclides. The matrix that binds may shift from algae, or other labile food substrates, to mineral surfaces due to deposit-feeder gut passage. These findings indicate that chemical changes due to gut passage may be as important in bioturbation modeling as spatial displacement of sediment during gut passage. Our studies of phytoplankton pigment degradation in deposit feeder digestive fluids indicate that these may be useful indicators of deposit-feeder gut passage in the field and could be measured in combination with radionuclides to determine both sediment mixing and gut passage frequency in the field.

## TRANSITIONS

Our results from this and previous ONR projects are being used to develop an artificial gut fluid to measure bioavailable contaminants in harbor dredge spoils, in a project funded by the U.S. Army Corps of Engineers.

## RELATED PROJECTS

Our ligand identification and ongoing frequency of gut passage work enhance the basis for our Corps of Engineers project. We are also continuing our collaboration with Dr. B. Boudreau's bioturbation modelling, research program, which involves mutual visits, seminars and discussions. His model design should benefit from our findings, and his models will allow tests of their implications after scaling to community and system levels.

## **PUBLICATIONS**

- Chen, Z., L.M. Mayer, C. Quétel, O.F.X. Donard, R.F.L. Self, P.A. Jumars, and D.P. Weston, 2000. High concentrations of complexed metals in the guts of deposit-feeders, *Limnology and Oceanography*, 45:1358-1367.
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